

**Sea Level and Storm Surge Trends for the State of the Park Report Cape Hatteras  
National Seashore/Fort Raleigh national Historic Site/Wright Brothers National Memorial**  
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**Historical Trends**

Sea level in the region has shown a significant increase over the past century (Kemp et al. 2011). Analyses of causal factors attribute 20th century global temperature, precipitation, and sea level changes to greenhouse gas emissions from vehicles, power plants, deforestation, and other human activities (Intergovernmental Panel on Climate Change (IPCC 2007). Data from NOAA (2013) show that sea level has risen around Beaufort, NC over the last 60 years at the rate of 0.11 in/yr over 1953–2012. In addition, a large number of tropical storms have passed through the region. No hurricane-strength storms have passed directly over CAHA/FORA/WRBR between 1842 and 2011. However, many of the tropical storms that have moved over the region have intensified as they moved north.

**Future Projections**

The IPCC has coordinated research groups in projecting possible future climate under defined greenhouse gas representative concentration pathways (RCPs) (IPCC 2013). All emissions scenarios show that sea level and storm surge will substantially increase over the next century (Table 1). Global sea level projections by Vermeer and Rahmstorf (2009) show increases in the rate of sea level change overall (Table 1). Sea level data downscaled to Beaufort, NC indicate that the rate of rise is projected to be higher than the global average rate of sea level rise (Figure 1; Table 1).

The IPCC (2012) report's that storm intensity is likely to increase in the future. It can be expected that storm surges will increase as storm intensity increases, however the number of storms and their paths may not change. Presently, storm surges are predicted to reach up to 12.3 ft at the CAHA visitor center if a category 5 storm struck at high tide (Figures 2 and 3; Table 1).

**Status, Trends, Confidence**

Based on these data, it is recommended that both sea level rise and storm surge should be considered a significant concern to CAHA/FORA/WRBR and the surrounding region. It is expected that both of these factors will continue to increase in the future. The condition is expected to deteriorate as more land-based ice melts and ocean waters continue to warm. We have a very high degree of confidence that both storm surges and sea levels will rise in the future.

## References

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**Table 1.** Cape Lookout National Seashore sea level and storm surge trends.

	Mean	Units	Source
<b>Historical</b>			
Sea level, North Carolina 1900–2000	0.08 (2.1)	in/yr (mm/yr)	Kemp et al. (2011)
Sea level, Beaufort 1953–2012	0.11 (2.70)	in/yr (mm/yr)	NOAA (2013)
Number of tropical storms, depressions, and subtropical storms to directly strike either CAHA, FORA, or WRBR 1842–2011	30	n/a	IBTrACS (2010)
Number of tropical storms, depressions, and subtropical storms paths within 10 miles of either CAHA, FOR A, or WRBR, 1842–2011	53	n/a	IBTrACS (2010)
Number of hurricanes to directly strike either CAHA, FOR A, or WRBR, 1842–2011	0	n/a	IBTrACS (2010)
Number of hurricanes paths within 10 miles of either CAHA, FOR A, or WRBR, 1842–2011	0	n/a	IBTrACS (2010)
<b>Global Sea Level Projections</b>			
IPCC RCP2.6 <sup>1</sup> global scenario sea level by 2065	0.79 (0.24)	ft (m)	IPCC (2013)
IPCC RCP4.5 global scenario sea level by 2065	0.85 (0.26)	ft (m)	IPCC (2013)
IPCC RCP6.0 global scenario sea level by 2065	0.82 (0.25)	ft (m)	IPCC (2013)
IPCC RCP8.5 global scenario sea level by 2065	0.95 (0.29)	ft (m)	IPCC (2013)
IPCC RCP2.6 global scenario sea level by 2100	1.31 (0.40)	ft (m)	IPCC (2013)
IPCC RCP4.5 global scenario sea level by 2100	1.54 (0.47)	ft (m)	IPCC (2013)
IPCC RCP6.0 global scenario sea level by 2100	1.54 (0.47)	ft (m)	IPCC (2013)
IPCC RCP8.5 global scenario sea level by 2100	2.03 (0.62)	ft (m)	IPCC (2013)

<sup>1</sup> Representative concentration pathways (RCPs) replace the previously used SRES scenarios used in previous reports by the IPCC. Each RCP is based on target radiative forcing of approximately 2.6, 4.5, 6.0, and 8.5 W m<sup>-2</sup> by 2100.

## USACE Sea Level Projections for Beaufort, NC

### *Low (historical rate) scenario:*

2030	0.31 (0.09)	ft (m)	USACE (2013)
2050	0.47 (0.14)	ft (m)	USACE (2013)
2100	0.88 (0.27)	ft (m)	USACE (2013)

### *Intermediate scenario:*

2030	0.44 (0.13)	ft (m)	USACE (2013)
2050	0.77 (0.24)	ft (m)	USACE (2013)
2100	1.92 (0.59)	ft (m)	USACE (2013)

### *High scenario:*

2030	0.85 (0.26)	ft (m)	USACE (2013)
2050	1.72 (0.52)	ft (m)	USACE (2013)
2100	5.21 (1.59)	ft (m)	USACE (2013)

## Estimated Storm Surge Heights<sup>2</sup> By Location

### *CAHA visitor center and Cape Hatteras*

### *Lighthouse (Buxton)*

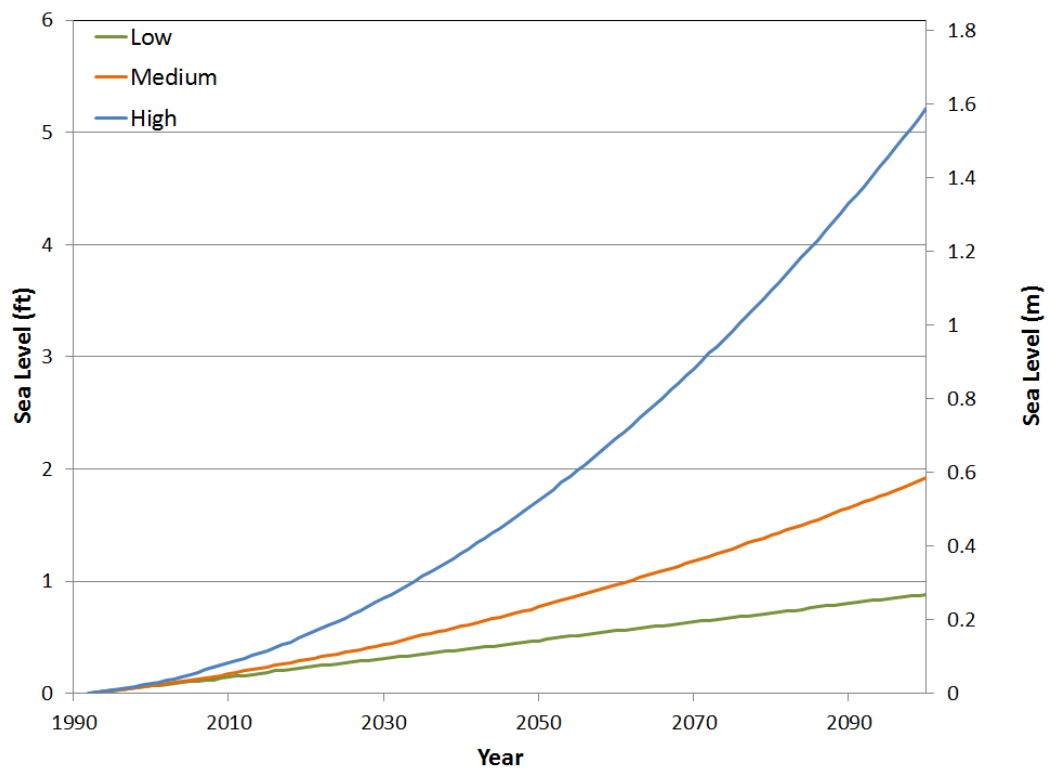
Saffir-simpson category 2 @ mean tide	7.9 (2.4)	ft (m)	NOAA SLOSH <sup>3</sup>
Saffir-simpson category 3 @ mean tide	10.3 (3.1)	ft (m)	NOAA SLOSH
Saffir-simpson category 4 @ mean tide	10.7 (3.26)	ft (m)	NOAA SLOSH
Saffir-simpson category 5 @ mean tide	11.7 (3.6)	ft (m)	NOAA SLOSH
Saffir-simpson category 2 @ high tide	9.5 (2.9)	ft (m)	NOAA SLOSH
Saffir-simpson category 3 @ high tide	10.4	ft	NOAA SLOSH

<sup>2</sup> Storm surge heights are projected on top of current mean sea level. It should be expected that potential storm surge heights will change over time based on changes in mean sea level.

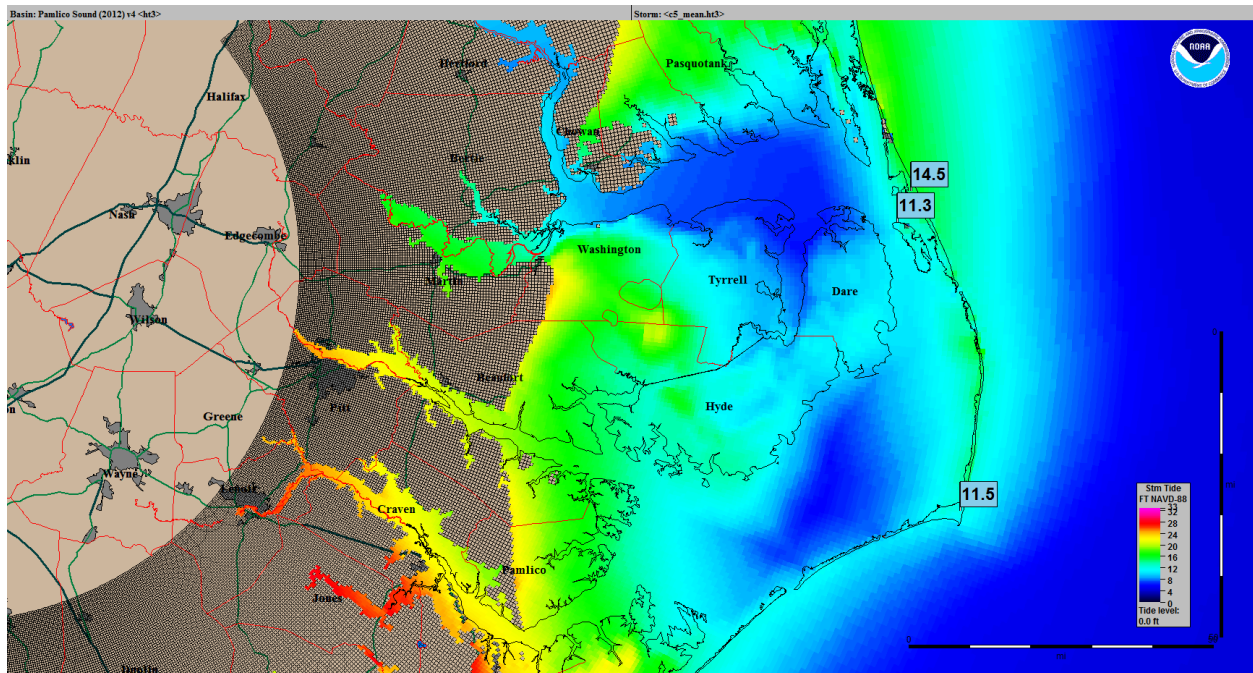
<sup>3</sup> Based on NOAA SLOSH MOM projections run by M.A. Caffrey using Pamlico Sound (2012) v4 basin data.

	(3.2)	(m)	
Saffir-simpson category 4 @ high tide	11.2	ft	NOAA SLOSH
	(3.4)	(m)	
Saffir-simpson category 5 @ high tide	12.3	ft	NOAA SLOSH
	(3.7)	(m)	
<i>Fort Raleigh National Historic Site</i>			
Saffir-simpson category 2 @ mean tide	6.1	ft	NOAA SLOSH
	(1.9)	(m)	
Saffir-simpson category 3 @ mean tide	8.8	ft	NOAA SLOSH
	(2.7)	(m)	
Saffir-simpson category 4 @ mean tide	10.4	ft	NOAA SLOSH
	(3.2)	(m)	
Saffir-simpson category 5 @ mean tide	11.3	ft	NOAA SLOSH
	(3.4)	(m)	
Saffir-simpson category 2 @ high tide	7.8	ft	NOAA SLOSH
	(2.4)	(m)	
Saffir-simpson category 3 @ high tide	9.7	ft	NOAA SLOSH
	(3.0)	(m)	
Saffir-simpson category 4 @ high tide	11.1	ft	NOAA SLOSH
	(3.4)	(m)	
Saffir-simpson category 5 @ high tide	11.7	ft	NOAA SLOSH
	(3.6)	(m)	
<i>Wright Brothers National Memorial</i>			
Saffir-simpson category 2 @ mean tide	Dry	ft	NOAA SLOSH
	(Dry)	(m)	
Saffir-simpson category 3 @ mean tide	11.5	ft	NOAA SLOSH
	(3.5)	(m)	
Saffir-simpson category 4 @ mean tide	13.5	ft	NOAA SLOSH
	(4.1)	(m)	
Saffir-simpson category 5 @ mean tide	14.5	ft	NOAA SLOSH
	(4.4)	(m)	
Saffir-simpson category 2 @ high tide	Dry	ft	NOAA SLOSH
	(Dry)	(m)	
Saffir-simpson category 3 @ high tide	12.3	ft	NOAA SLOSH
	(3.7)	(m)	
Saffir-simpson category 4 @ high tide	13.6	ft	NOAA SLOSH
	(4.1)	(m)	
Saffir-simpson category 5 @ high tide	14.9	ft	NOAA SLOSH
	(4.5)	(m)	

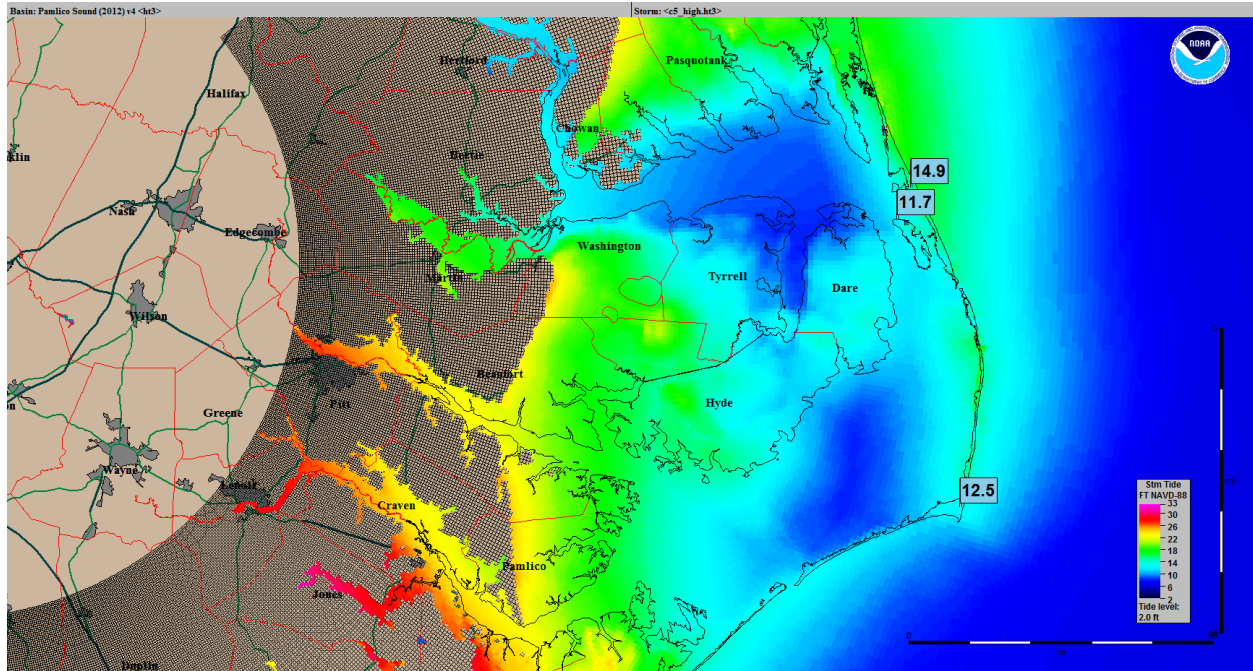
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**Figure 1: Projected rate of sea level rise for Beaufort, NC (USACE 2013)**



**Figure 2: Storm surge (ft.) for a category 5 storm at mean tide (prepared by M. Caffrey using NOAA SLOSH).**



**Figure 3: Storm surge (ft.) for a category 5 storm at high tide (prepared by M. Caffrey using NOAA SLOSH).**